

REPORT

FINAL REPORT

**Experimental Evaluation of
the Corrosive Potential of
Flux Residue Cleaning Agents**

to

NEWARK AIR FORCE BASE

(AGMC/MAEL)

January 31, 1992

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

19960520 008

 **Battelle**
... Putting Technology To Work

DTIC QUALITY INSPECTED 1



**505 King Avenue
Columbus, Ohio 43201-2693
Telephone (614) 424-6424
Facsimile (614) 424-5263**

Ms. Patty McWilliams
Department of the Air Force
AD-SEC/FME(2)
Wright AFB, Ohio 43057-5320

FINAL REPORT
CONTRACT NO. F09603-90-D-2217,
DELIVERY ORDER Q001

Enclosed are five (5) copies of the Final Report for the subject investigation task in accordance with CDRL A0002 of the delivery order referenced above. Please distribute a copy of the report to Captain Letourneau at AGMC/MAEL.

SECRET

Robert H. Frause
Program Manager

cc: ~~SECRET, FRODO (Copy 2 - Insurance)~~
DCASMA-Dayton [Letter only]

Enclosures

FINAL REPORT

on

**EXPERIMENTAL EVALUATION OF THE CORROSIVE
POTENTIAL OF FLUX RESIDUE CLEANING AGENTS
Contract No. F09603-90-D-2217, Delivery Order Q801**

to

**NEWARK AIR FORCE BASE
(AGMC/MAEL)**

January 31, 1992

by

J. T. Stropki and G. O. Davis

**BATTELLE
505 King Avenue
Columbus, Ohio 43201**

This report is a work prepared for the United States Government by Battelle. In no event shall either the United States Government or Battelle have any responsibility or liability for any consequences of any use, misuse, inability to use, or reliance upon the information contained herein, nor does either warrant or otherwise represent in any way the accuracy, adequacy, efficacy, or applicability of the contents hereof.

This report is approved for public release; distribution is unlimited.

	<u>Page</u>
INTRODUCTION	1
TECHNICAL APPROACH	2
EXPERIMENTAL PROCEDURES	2
Materials	3
Test Specimens	3
Specimen Identification	4
Specimen Preparation	6
Cleaning Compounds	9
Test Exposure	9
RESULTS AND DISCUSSION	11
CONCLUSIONS	22
REFERENCES	23

LIST OF FIGURES AND TABLES

Figure 1.	Diagram Documenting Four Regions on Test Specimen	8
Figure 2.	Photograph Documenting Placement of Test Specimens and Specimen Racks Within Environmental Test Chamber	10
Figure 3.	Photomicrograph Documenting Corrosion Pitting on Specimen 7212	14
Figure 4.	Photomicrograph Documenting Corrosion Damage on Surface of Specimen 6123	15
Figure 5.	Photomicrograph Documenting Minimal Corrosion on Representative Surface of Specimen 7123 Beneath Coating Blister	16
Figure 6.	Photomicrographs Documenting Minimal Amount of Corrosion Damage on Specimens 1312 and 1412	19
Figure 7.	Photomicrographs Documenting Noncorroded Surfaces of Specimens 1421 and 1321	20
Figure 8.	Photomicrographs Documenting Noncorroded Surfaces of Specimens 2112 and 4123	21
Table 1.	Specimens with Evidence of Corrosion Examined at 250X.	13
Table 2.	Representative Specimens with no Clear Evidence of Corrosion Examined at 250X.	18

EXECUTIVE SUMMARY

The results obtained from this study were used to assess the potential corrosion problems associated with using an aqueous (MSI-7000) flux remover for electronic and mechanical equipment repairs. This candidate cleaner is being considered as a replacement for the solvent (chlorofluorocarbon and chlorinated hydrocarbon) cleaners that are currently being used at the Aerospace Guidance and Metrology Center (AGMC) which is located in Newark, Ohio. Technical specialists at AGMC/MAEL and Battelle were responsible for developing a test plan which would quantify the level of corrosion occurring on specimens that were configured to simulate all material/coating combinations found at AGMC.

Testing included the exposure of numerous coated test specimens to a warm, humid environment. Post-test microscopic and metallographic examinations then were performed to determine the level of subcoating corrosion damage on specimens containing flux/cleaner residues. A comparison between the damage noted on control (nonfluxed) specimens, and specimens that were fluxed and cleaned with both an aqueous and a solvent cleaner were made. The results of these examinations confirmed that the candidate water-based cleaner did not promote any more corrosion on the surfaces of the tested specimens than did the conventional solvent cleaners. In most instances, the extent of damage occurring beneath the various coatings applied to several substrates (bare and plated) which simulated both circuit board and casing materials was considered minimal. Neither cleaner promoted appreciable amounts of corrosion after four weeks of exposure to the test environment.

The most corrosion noted on any one specimen was measured on two steel specimens (7212 and 7213) that were cleaned with a conventional solvent (isopropyl alcohol) cleaner and coated with a MIL-C-83286B coating system. For these specimens, the maximum depth of pitting corrosion attack measured less than 0.001 inch which represents less than two percent of the specimens available wall thickness. Superficial (less than 0.0003 inch) pitting corrosion was detected on the majority of the test specimens that were tested during this study.

The water-based detergent cleaner can be used as a replacement to conventional solvent flux cleaners. The results of this study indicate that the MSI-7000 aqueous cleaner is no more corrosive to circuit board and casing materials than is the solvent cleaner that is currently being used at AGMC. However, it is recommended that AGMC/MAEL use adequate cleaning procedures to ensure the complete removal of flux/cleaner residues from the casing materials, and subsequent elimination of coating blisters or defects.

FINAL REPORT

on

EXPERIMENTAL EVALUATION OF THE CORROSIVE POTENTIAL OF FLUX RESIDUE CLEANING AGENTS Contract No. F09603-90-D-2217, Delivery Order Q801

to

**NEWARK AIR FORCE BASE
(AGMC/MAEL)**

January 31, 1992

INTRODUCTION

The Aerospace Guidance and Metrology Center (AGMC) which is located at the Newark Air Force Base (NAFB) in Newark, Ohio, is responsible for repairing inertial navigation and guidance equipment for the United States Air Force (USAF) and other Department of Defense (DOD) agencies. The Center repairs thousands of these delicate, sophisticated electromechanical devices each year. Increasing environmental and personnel safety concerns has prompted AGMC personnel to consider the replacement of solvent (chlorofluorocarbon and chlorinated hydrocarbon) cleaners that currently are being used to remove residual RMA (mildly activated rosin) soldering flux from electronic components and equipment casings after repairs. Proposed alternatives include safer and more environmentally acceptable water-based detergent cleaners. However, the basic problem with any solvent or water-based cleaner used for removing flux from soldered surfaces is that, in practice, some residue of flux and/or cleaner remains on the surfaces of components after cleaning. These components then are coated with a paint or conformal spray coating before the repaired item is returned to service. Hence, after continuous exposure to certain environments, this entrapped residue may promote localized corrosion on the component. This study was initiated to determine if corrosion problems develop when repaired and cleaned (solvent or water-based detergent cleaners) systems are returned to normal field service. The presence of corrosion on these components will adversely affect the reliability, maintainability and service life of the associated systems.

TECHNICAL APPROACH

This program was designed to assess the potential corrosion problems associated with the use of a candidate water-based flux remover (MSI-7000) for electronic and mechanical equipment repairs. Testing included the exposure of coated specimens to a warm, humid environment for thirty days followed by an examination for corrosion initiating beneath the coatings as a result of flux/cleaner residues. For comparison purposes, a set of specimens cleaned with a conventional solvent (isopropyl alcohol) cleaner, as well as a set of control (nonfluxed) specimens were also exposed to this test environment.

Test specimens consisted of 1.0 inch x 3.0 inch strips of various metals, with and without plating, that are commonly used in electronic circuit board and casing applications. Sections on all specimens were coated with mildly activated rosin (RMA) soldering flux, cleaned to various degrees with either conventional solvents or the alternative aqueous detergent cleaner so as to intentionally leave flux and cleaner residues on portions of these surfaces. The specimens then were coated with various types of conformal coatings and paint systems. After exposure, these sections and two other sections on each specimen were examined by unaided visual inspection and then examined microscopically to identify any corrosion which may have resulted from the various residues. The results of all examinations and analyses obtained during this program are provided in this final report.

EXPERIMENTAL PROCEDURES

A review of the materials, instrumentation and protocol used in performing this study are detailed in the following text. As required by the Statement-Of-Work (SOW), a test plan summarizing all technical activities which were to be performed during this program was submitted to Newark AFB (AGMC/MAEL). This test plan was approved on August 22, 1991 and was followed throughout the study.

Materials

Test Specimens

A total of 279 test specimens, each measuring 1.0 inch x 3.0 inch, were supplied to Newark AGMC/MAEL. The composition of individual specimens varied according to whether the specimens were simulating circuit board trace and connection components, or casing components. A summary of the types of materials, and applicable plating specifications provided by the various vendors responsible for finishing the specimens, is provided in the following sections:

Circuit Boards (45 specimens/material)

- Bare Copper Sheet, Alloy C 11000 (electrolytic tough-pitch copper)
 - 0.060-inch thick
- Copper Sheet Electroplated with a Tin/Lead Alloy
 - 0.060-inch thick copper sheet, Alloy C 11000
 - matte tin/lead (60/40) plating (AMAX Plating Inc.)
 - 200 microinches minimum thickness in accordance with MIL-P-81728
- Copper Sheet Electroplated with a Thin Layer of Gold over a Nickel Base-plate
 - 0.060-inch thick copper sheet, Alloy C 11000
 - 0.000050-inch thick sulfamate nickel plating (Precision Plating Inc.)
 - 0.000030-inch thick hard gold plating (Precision Plating Inc.)

Casings (36 test specimens/material)

- Bare Aluminum Sheet
 - 0.060-inch thick, Alloy 6061 (Metal Samples Inc.)
- Bare Copper Sheet
 - 0.060-inch thick, Alloy C 11000
 - included to simulate the copper strike used for soldering

- Copper Sheet Electroplated with a Tin/Lead Alloy
 - 0.060-inch copper sheet, Alloy C 11000
 - matte tin/lead (60/40) plating (AMAX Plating Inc.)
 - 200 microinches minimum thickness in accordance with MIL-P-81728
- Steel Sheet
 - 0.060 inch thick, AISI 1020 (Metal Samples Inc.)

Pre-test processing of the individual test specimens included the stamping of a four-digit code to the edges of each specimen, followed by a thorough ultrasonic cleaning in 200 proof ethyl alcohol. Details relevant to the procedures used to process and test the individual specimens are provided in the following text.

Specimen Identification

The identity of all materials and pertinent preparation requirements were documented by stamping each specimen with a four digit number near the edge on the side opposite the side coated with flux. All numbers were positioned near the end of the specimen which was heated to simulate the effects of soldering.

The first digit of the numeric code designated the type of material which was used in preparing the specimen. A summary of the various materials and corresponding numeric codes is provided as follows:

<u>Component</u>	<u>Code</u>	<u>Material</u>
Circuit Board	1	Bare copper
	2	Tin/lead plated copper
	3	Gold plated copper
Casing	4	Bare copper
	5	Tin/lead plated copper
	6	Aluminum
	7	Steel

The second digit, 1 through 5 for the circuit board materials and 1 through 4 for the casing materials, corresponds to the type of coatings applied to the various materials. A summary defining the individual coatings, application methods (spray or brush), and corresponding numeric codes is provided by the following:

<u>Component</u>	<u>Code</u>	<u>Coating</u>	<u>Application</u>
Circuit Board	1	Uralite 1263 (A/B)	Brush (24 hour cure)
	2	Humsol 1B15H	Spray (1 hour cure)
	3	Conformal C 1-2577	Brush (24 hour cure)
	4	Hysol PC18M	Brush (3-4 hour cure)
	5	Hysol PC20M	Brush (3-4 hour cure)
Casing	1	MIL-C-83286D Type I&II (Black)	Spray (24 hour cure)
	2	MIL-C-83286B Type I&II (Grey)	Spray (24 hour cure)
	3	MIL-E-52798 (Camouflage Green)	Spray (24 hour cure)
	4	TT-E-485F Type II (Olive Green)	Spray (24 hour cure)

The third digit of the numeric code designated the type of cleaning process used in preparing the individual test specimens. An identification of these cleaners and corresponding code is as follows:

<u>Digit</u>	<u>Cleaning Procedure</u>
1	Conventional solvent
2	Water-based detergent
3	Nonfluxed control

The final digit indicated the specific specimen number out of the three replicated specimens used for each material/coating/cleaning combination.

Specimen Preparation

As stated in the previous text, all test specimens were stamped with a numeric code, thoroughly cleaned with 200 proof ethyl alcohol, and packaged with desiccant prior to being transported to AGMC for application of the flux cleaner. After cleaning, a set of representative specimens was treated at AGMC to produce flux residues simulating those found on cleaned circuit board and casing components, while others were used in the "as-cleaned" condition. Flux-residue-bearing specimens were produced using the following procedure. First a set of specimens was loaded into a fixturing device which was designed by Air Force personnel to (1) secure all specimens, and (2) simplify the specimen preparation procedures. Then approximately one-half of each specimen was coated with flux and exposed to a high temperature through contact with a special wide tipped soldering iron. Air Force personnel performing this task used approximately the same contact time as would be used in soldering a similarly sized component in practice. Next, approximately one-half of the heated portion of the specimen was cleaned with either the conventional or the alternative (water-based detergent) cleaner. Fresh cloths were used to clean each specimen, thereby, reducing the possibility of cross-contamination. Baths and containers containing the respective cleaners were not contaminated with flux residues, therefore, a minimal amount of specimen-to-specimen contamination was anticipated as a result of the cleaning processes. Finally, a small drop of cleaner was placed on the baked flux remaining on the specimen within the uncleaned region. This simulated a condition of incomplete flux and cleaner removal. A pipette was used to assure that a uniform amount of cleaner was placed on each specimen within the region containing the baked-on flux.

The other half of the processed specimens was similarly prepared, except that this half was not heated after the initial coating of flux was applied. Half of the unheated portion of the specimen was cleaned, and the other half contained a drop of cleaner added using a pipette. Thus, there were four distinct regions on each specimen: (1) baked flux with cleaner, (2) baked flux which was cleaned, (3) unbaked flux which was cleaned, and (4) unbaked flux with cleaner. This configuration provided all four conditions of flux and cleanliness on a single 1.0 inch x 3.0 inch test specimen. Figure 1 illustrates the four regions on a single specimen. All specimen preparation procedures were performed in controlled humidity

rooms, with actual humidity and temperature measurements recorded during the entire preparation process. A summary of these measurements is provided in Appendix A.

After completing the simulated soldering and cleaning activities, the appropriate specimens were affixed to special styrofoam pads and coated with either one of the conformal coatings used for the circuit board specimens, or one of the coatings used for the casings. These processes were performed at AGMC by Air Force personnel experienced in coating application. All coatings were applied as uniformly as possible, and to the most consistent thicknesses possible for the different specimens. Specimens were coated only on the side containing the flux and cleaner deposits. Possible cross-contamination between the four distinct regions on specimens coated with the conformal coatings (circuit board components) was minimized by applying the coatings across the short, i.e., 1-inch, dimension of the specimens. A separate brush was used for the same section on a representative set of specimens. A separate set of brushes was used for the four types of coatings that were brushed on the circuit board specimens. Coating uniformity was ensured by applying all coatings (containing fluorescent dye) under a black light bulb. All coated circuit board specimens were allowed to air dry for approximately 16 hours prior to being transferred from the Modular Repair Facility to the AGMC/MAEL Engineering Facility. Additionally, these specimens and the coated casing specimens were allowed to air dry and cure for a minimum of 48 hours prior to being transported to Battelle and tested within an environmental chamber. Humidity and temperature measurements were recorded during the painting and storage of all specimens.

An abbreviated summary of the preparation procedures employed by AGMC personnel is as follows:

1. Coat one-half of the specimen with soldering flux (left half in Figure 1),
2. Heat this half of the specimen with a soldering iron,
3. Clean the outermost half of the fluxed region (see Figure 1),
4. Place a drop of cleaner on the uncleaned region containing the baked flux,
5. Coat the other half of the specimen (right half in Figure 1) with flux,
6. Clean the outermost half of this side of the specimen,
7. Place a drop of cleaner in the region of unbaked, uncleaned flux,
8. Coat the entire specimen with either paint or conformal coating.

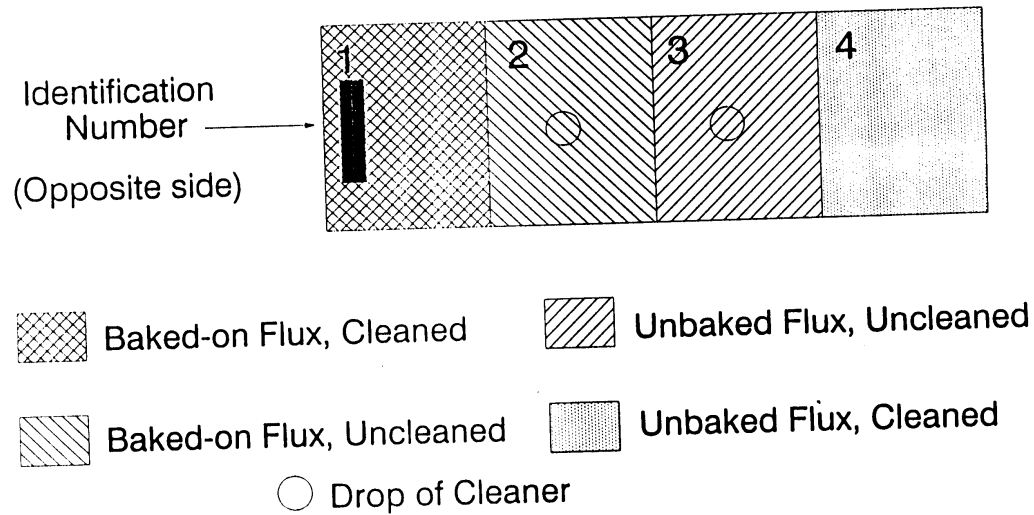


FIGURE 1 ILLUSTRATION OF TEST SPECIMEN CONFIGURATION DOCUMENTING FOUR REGIONS ON TEST SURFACE AND PLACEMENT OF IDENTIFICATION NUMBER

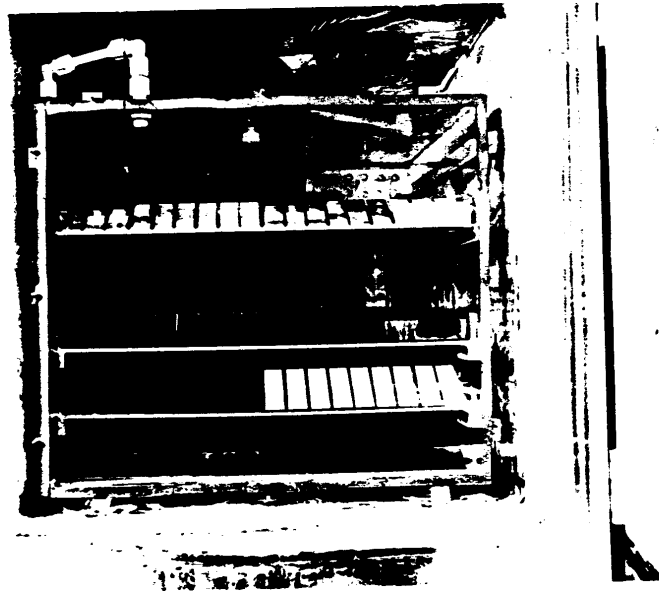
Cleaning Compounds

The two types of flux cleaners that were selected and used for this study were (1) isopropyl alcohol, and (2) MSI 7000. The latter is a water-based cleaner which is manufactured by Magnasonic Systems Incorporated. Technical information related to the ingredients and toxicity of this product are noted in the MSDS sheets that are provided in Appendix B.

Test Exposure

All specimens were loosely mounted, at an angle of 15 degrees from vertical, within fourteen separate Plexiglas® specimen holders. This angle was selected to minimize the possibility of condensate collection along the coated surfaces of the specimens. Each rectangular-shaped holder was 21 inches long, which allowed Battelle technicians to mount a total of 18 specimens into a single holder. In most instances, six sets of triplicate specimens were positioned within each holder and loaded onto several racks located throughout the environmental test chamber. A spacing of approximately 0.125 inch was maintained between all specimens during the 1-month test exposure period. Identification labels for each specimen were affixed to the front lower surfaces of the specimen holders. These labels were quite useful when visually examining and photographing the numerous sets of specimens mounted within the specimen holders.

The environmental test chamber used for this study was an Associated Testing Laboratories Model HB-4108 cabinet. All test conditions (temperature, humidity and air flow/exchange rates) were preset and automatically controlled by the unit throughout the duration of the test exposure period. Documentation of the placement of the specimens and the specimen holders within the test chamber is provided in Figure 2. The position of each specimen holder within the chamber was changed after each of the three weekly visual inspections completed for the set of specimens. This was not a required procedure because the humidity and temperature within the 24 inch x 24 inch Plexiglas® chamber remained constant throughout the 1-month exposure period, and the exchange rate of the air within the chamber was minimal.



**FIGURE 2. PHOTOGRAPH DOCUMENTING PLACEMENT OF TEST SPECIMENS
AND SPECIMENS RACKS WITHIN ENVIRONMENTAL TEST CHAMBER**

As stated in the approved test plan, the conditions within the test chamber were set and maintained at 90 percent relative humidity and 100 F. Daily measurements confirmed that the unit maintained these conditions throughout the duration of the exposure period.

The test chamber was only shut-down three times during the 1-month exposure period. Each two-hour shut-down was necessary to perform the required weekly visual examinations of the coated surfaces on the individual specimens. These surfaces also were photographed at each interval to document the extent of any corrosion which may have developed on the specimens. All photographs have been submitted to Air Force personnel at Newark AGMC/MAEL.

Post-test processing of the individual specimens included mounting each specimen in an epoxy block. This procedure ensured the integrity of the coating-to-metal interface and preserved any corrosion deposits present on the surface of the specimens. Once mounted, all specimens were cut in the longitudinal direction to reveal the cross-section of the specimen. Nine of the halved sections, which represented nine separate specimens were then grouped together and remounted in a larger (2 inch x 4 inch) epoxy mount. Hence, a total of 279 metallographically cross-sectioned test specimens were mounted in 31 separate mounts. Each of these mounts were then metallographically polished to permit microscopic examination of any corrosion attack occurring beneath the coating systems applied to the individual specimens. The results of these examinations, as well as relevant photographic documentation of the magnitude of corrosion attack existing on any of the tested specimens is provided in the following section.

RESULTS AND DISCUSSION

Unaided visual examinations of all the specimens after exposure in the environmental test chamber indicated the possible presence of corrosion under the coatings of several specimens. Specimen No. 1412¹ was an example of these preliminary findings. Initial examinations also showed a significant number of blisters in the coatings on numerous

¹

Bare copper circuit board matrix, Hysol PC18M coating, conventional solvent cleaned, Specimen 2.

specimens. After each specimen was sectioned and mounted in epoxy metallographic mounts, all surfaces on the specimens within each mount were examined microscopically at a 100X magnification. Evidence of corrosion or other significant features were noted for each section examined at this magnification.

Further microscopic examinations at a magnification of 250X were performed on only those sections that showed notable features at the lower magnification. Photomicrographs also were taken at 250X to document representative examples of corrosion, or the lack of it, and any other pertinent features that were observed.

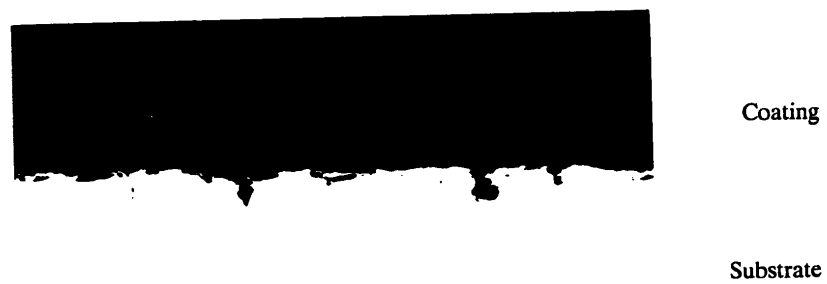
In general, the results of all examinations indicated that the water-based cleaner did not induce any more corrosion on the tested specimens than did the conventional solvent cleaner. Neither cleaner seemed to promote appreciable corrosion of any substrate or plating tested. All evidence of corrosion observed was judged to be relatively minor. Examination results also suggest that there is no definite correlation between the extent of corrosion observed for either type of component, i.e., casing or circuit board, the type of substrate or plated metal, the type of coating, or the type of cleaner/cleaning procedure used on the individual test specimens.

A summary of the processing procedures associated with the specimens having evidence of minor corrosion is provided in Table 1. As is shown, the greatest degree of corrosion observed on any of the specimens examined was noted on Specimens 7212 and 7213. A photomicrograph of a representative corroded area on Specimen 7212 is shown in Figure 3. This specimen is an example of steel casing cleaned by the conventional solvent. The tested surface of Specimen 7212 was slightly pitted during the test exposure, with the maximum pit depth measured at approximately 0.8 to 1 mil, i.e., .0008 to .001 inch. This value was determined by measuring the deepest pits on the photomicrograph and dividing the values by 250 to correct for the 250X magnification factor. It should be noted that Specimens 7212 and 7213 contained the greatest amount of corrosion of all the specimens examined and that they were cleaned with the conventional solvent and not the water-based cleaner.

Figure 4 is a photomicrograph of a representative surface on Specimen 6123 at 250X magnification. This specimen showed the second highest level of corrosion of the balance of specimens that were examined. This specimen represents an aluminum casing

TABLE 1. SPECIMENS WITH EVIDENCE OF CORROSION EXAMINED AT 250X

Four-Digit Specimen No.	Type Component	Substrate or Plating	Coating (spec)	Cleaning Procedure	Max. Depth of Attack or Comment
7212	Casing	Steel	Type 2 (MIL-C-83286B)	Type 1 conventional solvent	~ 0.8 to 1 mil (on Photo 50735)
6123	Casing	Al	Type 1 (MIL-C-83286D)	Type 2 water-based cleaner	Mix of minor general corrosion & shallow pits; max depth ~ 0.3 mil
1312	Circuit Board	Bare Cu	Type 3 (conformal) C 1-2577)	Type 1 conventional solvent	Minor surface attack
1412	Circuit Board	Bare Cu	Type 4 (HYSOL) PC18M	Type 1 conventional solvent	Minor surface attack



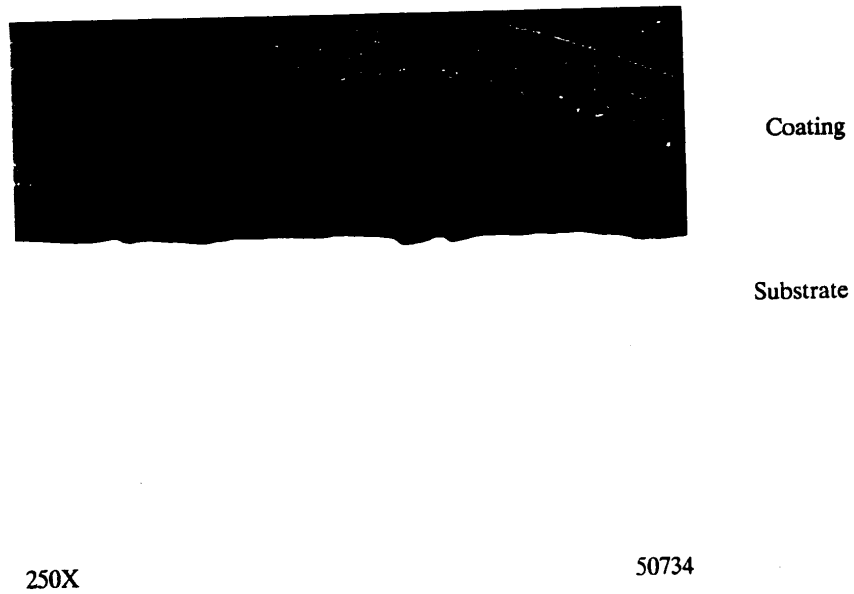
250X

50735

**FIGURE 3. PHOTOMICROGRAPH DOCUMENTING CORROSION PITTING
ON SPECIMEN 7212**



**FIGURE 4. PHOTOMICROGRAPH DOCUMENTING CORROSION DAMAGE
ON SURFACE OF SPECIMEN 6123
(Note coating blister above damaged substrate.)**



**FIGURE 5. PHOTOMICROGRAPH DOCUMENTING MINIMAL CORROSION
ON REPRESENTATIVE SURFACE OF SPECIMEN 7123
BENEATH COATING BLISTER**

component that had been cleaned with the water-based cleaner. The photomicrograph shows minor general corrosion and some shallow pits that have a maximum depth of about 0.3 mil, i.e., 0.0003 inch. It is difficult to see in the photograph of Figure 4 but there is a blister in the coating covering this particular region of Specimen 6123. Figure 5 is a photomicrograph of Specimen 7123 that had an approximately equal extent of minor corrosion as Specimen 6123 but the former was intended to clearly document a blister in the coating above the metal surface. This type of coating defect (blistering) was noted frequently during the initial unaided visual inspections, and very common in the examinations at higher magnifications.

Figure 6, (a) and (b), includes photomicrographs of Specimens 1312 and 1412, respectively, taken at 250X magnification. These photomicrographs represent typical examples of specimens that had minimal levels of surface corrosion as observed in these examinations. Processing variables associated with the two specimens are provided in Table 1. It should be noted that Specimen 1412 was identified in the initial unaided visual examinations, performed on all specimens, as one that might have significant subcoating corrosion damage. Apparently, our initial reactions were a result of severe coating damage on the specimen but the later metallographic inspections showed no substantial corrosion of the substrate copper.

Table 2 provides details of five specimens that are representative of the many specimens that were examined and found to have very minor or essentially no corrosion. Figure 7, (a) and (b), provides photomicrographs of Specimens 1321 and 1421, respectively, at 250X magnification. Figure 8 (a) and (b), similarly illustrate Specimens 2112 and 4123, respectively. As is shown in Table 2, that among this representative sample of specimens with essentially no corrosion, both conventional (solvent) and water-based cleaners were used for cleaning and the latter type was more common among this group of five specimens. This result confirms that the aqueous cleaner tested during this study was no more corrosive to electrical and casing components than was the solvent cleaner what is currently being used to remove flux and/or flux residues from these components.

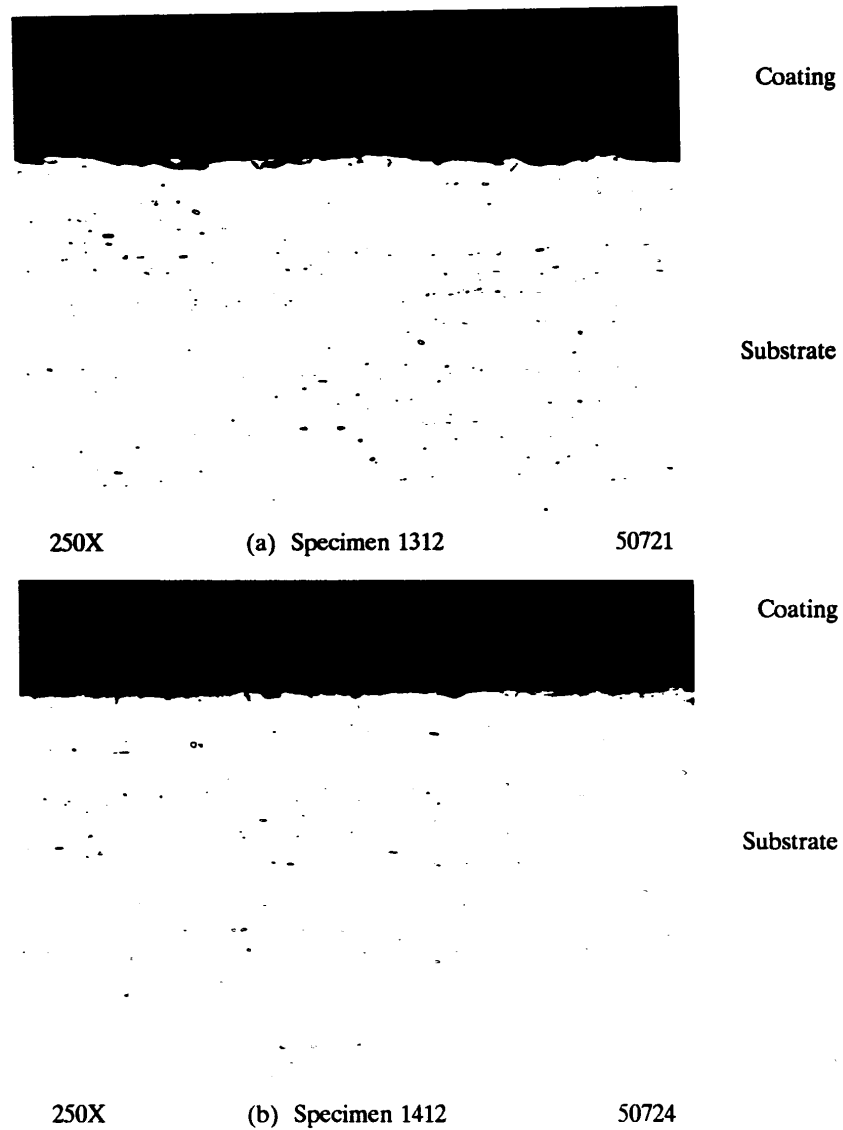
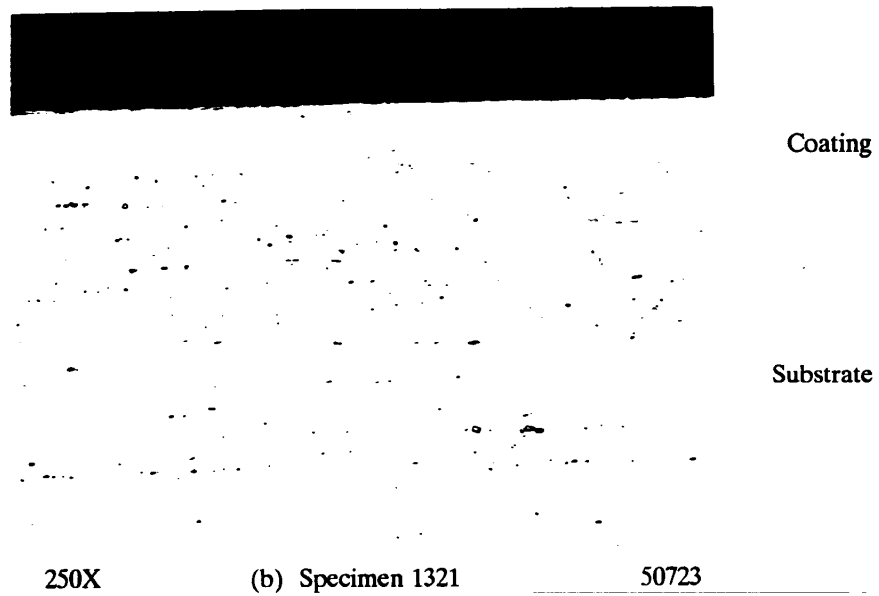
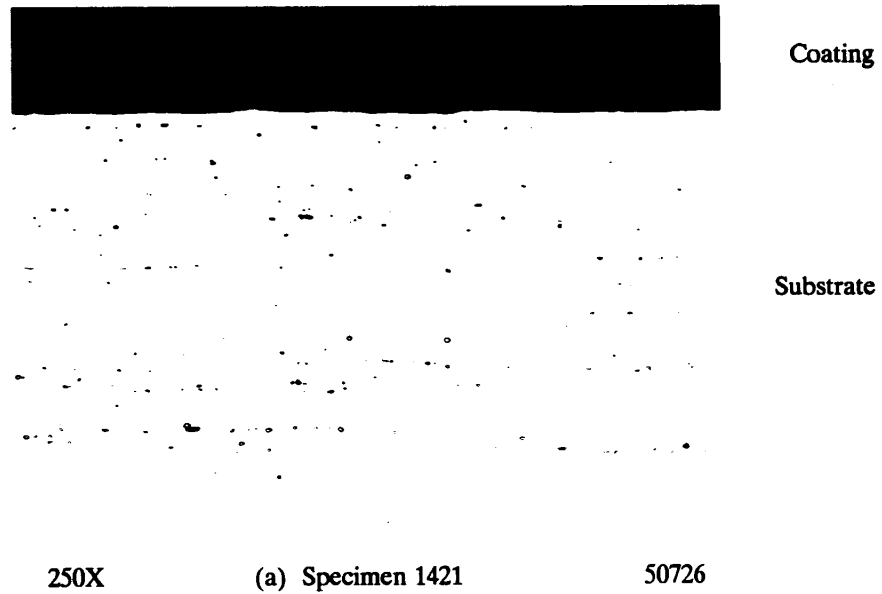


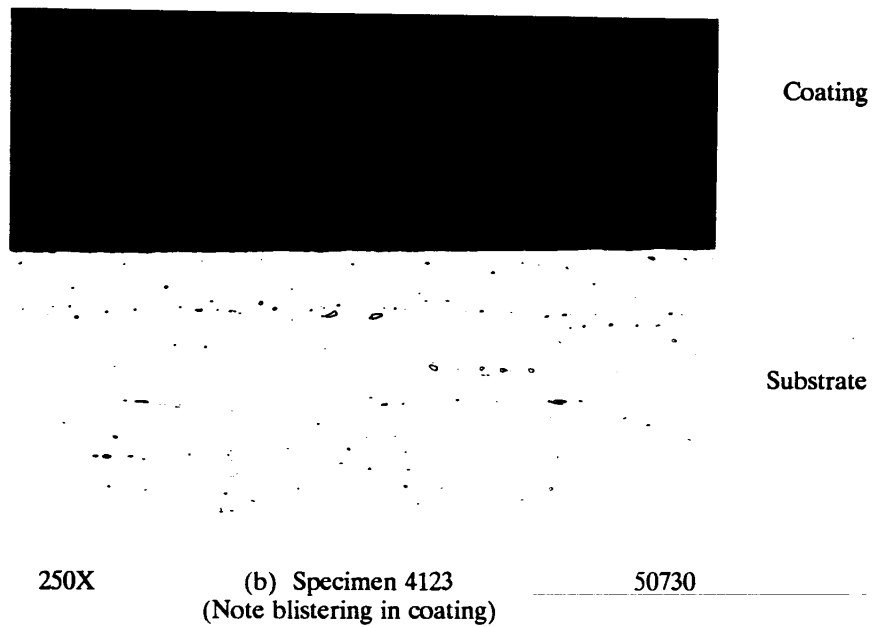
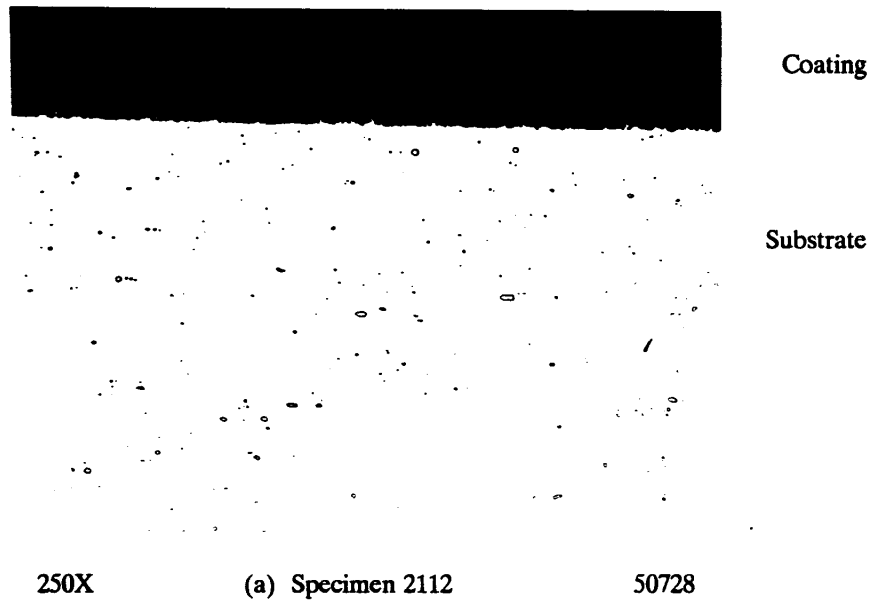
FIGURE 6. PHOTOMICROGRAPHS DOCUMENTING MINIMAL AMOUNT OF CORROSION DAMAGE ON SPECIMENS 1312 AND 1412

TABLE 2. REPRESENTATIVE SPECIMENS WITH NO CLEAR EVIDENCE OF CORROSION EXAMINED AT 250X

Four-Digit Specimen No.	Type Component	Substrate or Plating	Coating (spec)	Cleaning Procedure	Comments
7123 inside coating blister	Casing	Steel	Type 1 (MIL-C-83286D)	Type 2 water-based cleaner	Irregular steel surface but no evidence of attack; good example of blisters in coating
1421	Circuit Board	Bare Cu	Type 4 (HYSOL PC18M)	Type 2 water-based cleaner	No corrosion detected
1321	Circuit Board	Bare Cu	Type 3 (Conformal) (C 1-2577)	Type 2 water-based cleaner	No corrosion detected
2112	Circuit Board	Sn/Pb plated Cu	Type 1 (URALITE 1263 A/B)	Type 1 conventional solvent	No corrosion detected
4123 inside coating blister	Casing	Bare Cu	Type 1 (MIL-C-83286D)	Type 2 water-based cleaner	Negligible attack on Cu surface; poor example of coating blisters



**FIGURE 7. PHOTOMICROGRAPHS DOCUMENTING NONCORRODED SURFACES
SPECIMENS 1421 AND 1321**



**FIGURE 8. PHOTOMICROGRAPHS DOCUMENTING NONCORRODED SURFACES
SPECIMENS 2112 AND 4123**

CONCLUSIONS

A listing of the results obtained from this research program are summarized in the following conclusions:

- Microscopic and metallographic techniques were used to confirm that the MSI-7000 aqueous cleaner did not promote any more corrosion on the tested specimens than the isopropyl alcohol.
- The extent of corrosion occurring beneath the various coatings applied to several substrates (bare and plated), which simulated circuit board and casing materials, was considered minimal. Neither cleaner promoted appreciable amounts of corrosion after four weeks of exposure to a warm, humid environment.
- The most corrosion observed was measured on Specimens 7212 and 7213. These specimens had a steel substrate which was cleaned with the conventional solvent cleaner and coated with MIL-C-83286B. No corrosion was detected on similar specimens that were cleaned with the aqueous cleaner.
- A maximum pit depth of 0.8 to 1.0 mil (0.0008 to 0.001 inch) was measured for the attack on Specimen 7212.
- Superficial (less than 0.0003 inch) pitting corrosion was detected on the aluminum casing components that were cleaned with the water-based detergent cleaner and coated with MIL-C-83286D.
- The only corrosion detected on the circuit board materials occurred on the bare copper circuit board materials that were cleaned with the aqueous detergent cleaner and coated with the C 1-2577 and HYSOL PC18M con-formal coating systems. In both instances, the extent of damage was minimal.
- No differences exist between the level of corrosion occurring within the baked or unbaked flux residue regions of all specimens or the regions with or without cleaner residue.
- Coating blisters were noted within the uncleaned (baked and unbaked) regions of all specimens that were coated with the various casing paint systems. These defects most likely were a result of the flux residue that remained on the surfaces of the specimens and/or the droplet of cleaner that was placed on the surface.

REFERENCES

- (1) Statement of Work issued by Newark AFB (AGMC/MEAL), "Experimental Evaluation of the Corrosive Potential of Flux Residue Cleaning Agents", Document No. MAEL-GL-91-1, May 24, 1991.
- (2) Test Plan IAW CDRL A0001 issued by Battelle, "Experimental Evaluation of the Corrosive Potential of Flux Residue Cleaning Agents", Data Item A0001 of the SOW, August 22, 1991.

ACKNOWLEDGEMENT

The authors would like to acknowledge the technical contributions of Captain R. Campbell, Mr. Gene Ott, and Mrs. Madeline Johnson.

APPENDIX A

Humidity and Temperature Measurements

Run No. 1 -- Storage of Test Specimens at MAEL Facility

Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 1
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 28-Oct-91 09:15:20.
Finish : 31-Oct-91 10:44:38.
Readings per channel: 221

Channel 1 Statistics

Sample Period

Start 28-Oct-91 09:15:20. Finish 31-Oct-91 10:35:20.

Range = -57.96degF to 302.04degF

Minimum Value = 68.94degF

28-Oct-91 18:55:20.

Maximum Value = 77.49degF

31-Oct-91 09:15:20.

Mean = 73.49degF

Standard Deviation = 2.23

Variance = 4.987

Channel 9 Statistics

Sample Period

Start 28-Oct-91 09:15:20. Finish 31-Oct-91 10:35:20.

Range = 0.00% to 100.00%

Minimum Value = 21.20%

30-Oct-91 22:35:20.

Maximum Value = 33.40%

28-Oct-91 18:55:20.

Mean = 25.77%

Standard Deviation = 3.08

Variance = 9.508

Data file - NEWARK

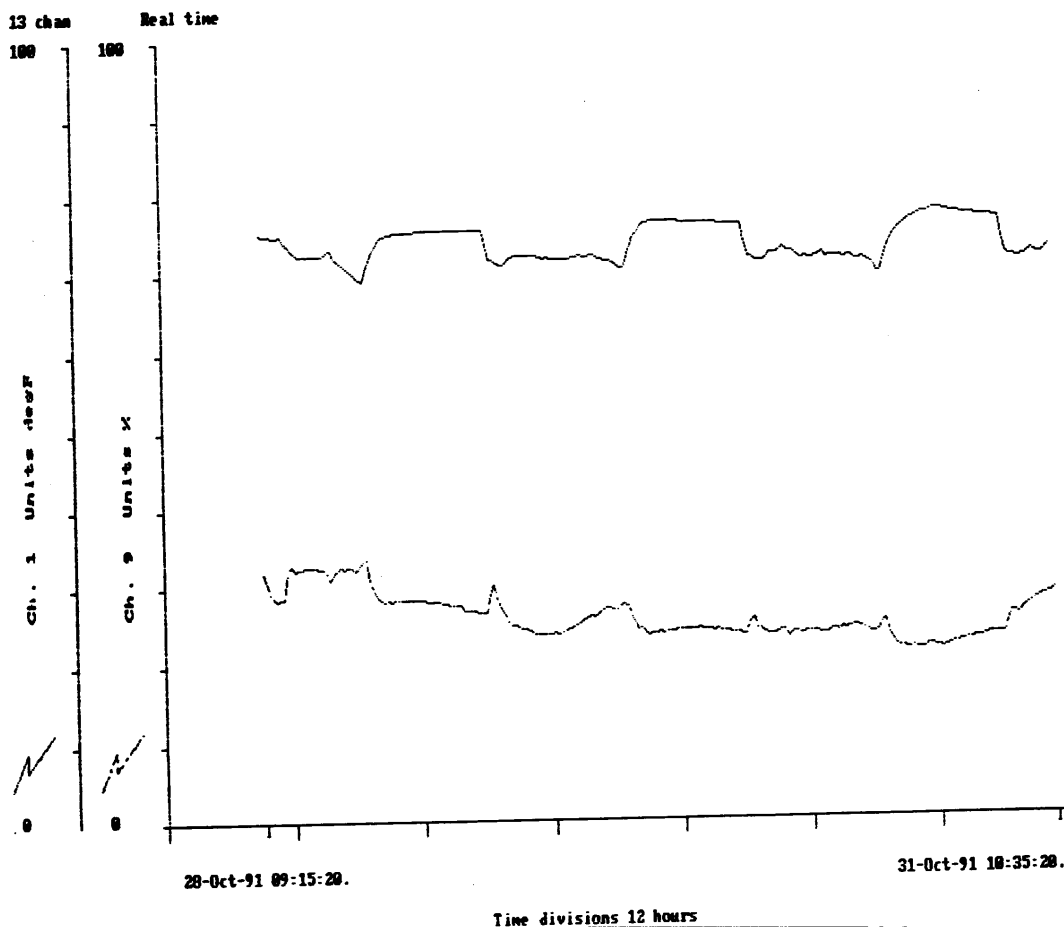
Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 1
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 28-Oct-91 09:15:20.
Finish : 31-Oct-91 10:44:38.

Readings per channel: 221



Analogue Graph Summary

Run No. 2 -- Transport of Test Specimens to Modular Repair Facility

Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 2
Channels used : 13
Recording Interval : 00:05:00.
Non-averaged time interval readings
Recording period :
Start : 31-Oct-91 10:45:21.
Finish : 31-Oct-91 12:26:34.
Readings per channel: 21

Channel 1 Statistics

Sample Period
Start 31-Oct-91 10:45:21. Finish 31-Oct-91 12:25:21.

Range = -57.96degF to 302.04degF
Minimum Value = 72.00degF 31-Oct-91 12:20:21.
Maximum Value = 73.26degF 31-Oct-91 10:50:21.
Mean = 72.77degF
Standard Deviation = 0.24
Variance = 0.058

Channel 9 Statistics

Sample Period
Start 31-Oct-91 10:45:21. Finish 31-Oct-91 12:25:21.

Range = 0.00% to 100.00%
Minimum Value = 27.00% 31-Oct-91 12:25:21.
Maximum Value = 31.60% 31-Oct-91 11:05:21.
Mean = 29.76%
Standard Deviation = 1.09
Variance = 1.186

Data file - NEWARK

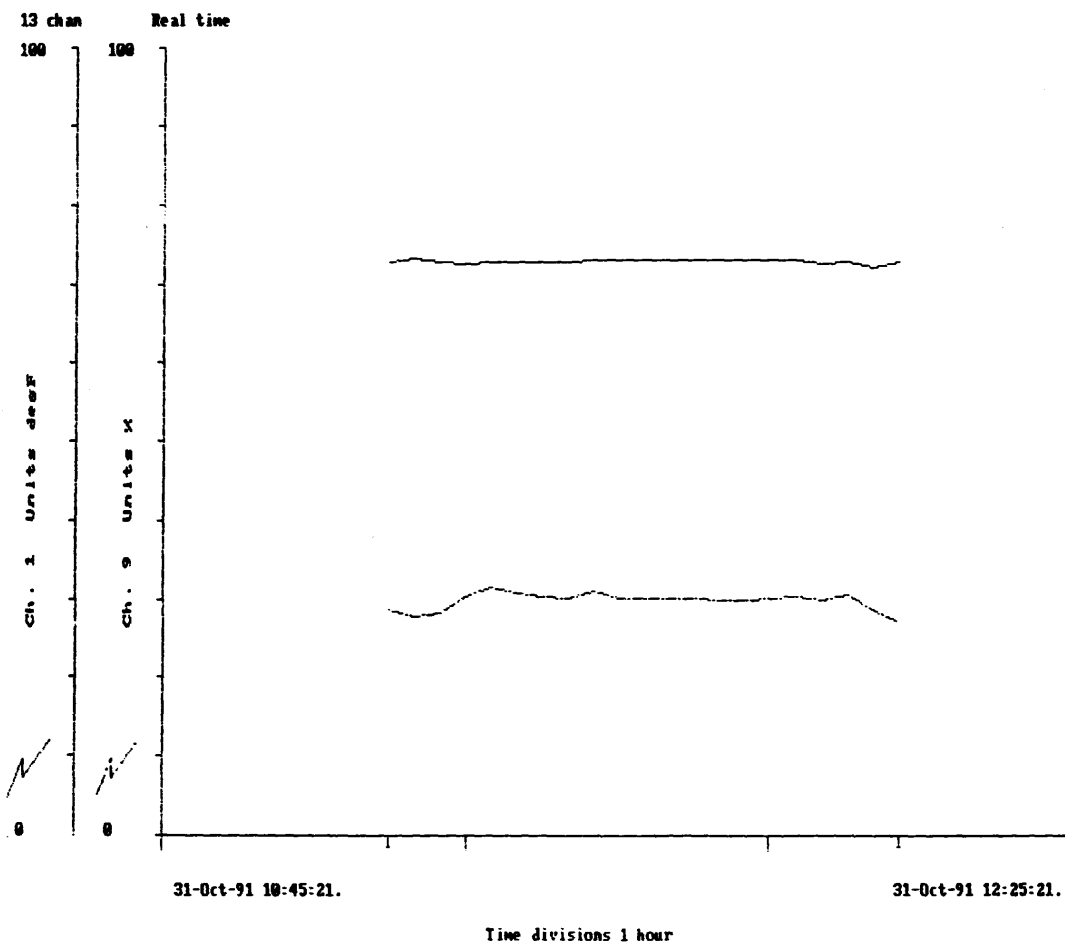
Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 2
Channels used : 13
Recording Interval : 00:05:00.
Non-averaged time interval readings
Recording period :
Start : 31-Oct-91 10:45:21.
Finish : 31-Oct-91 12:26:34.

Readings per channel: 21



Analogue Graph Summary

Run No. 3 -- Storage of Conformal Coated Test Specimens in MAE Facility

Run No. 4 -- Transport of Test Specimens to Paint Facility

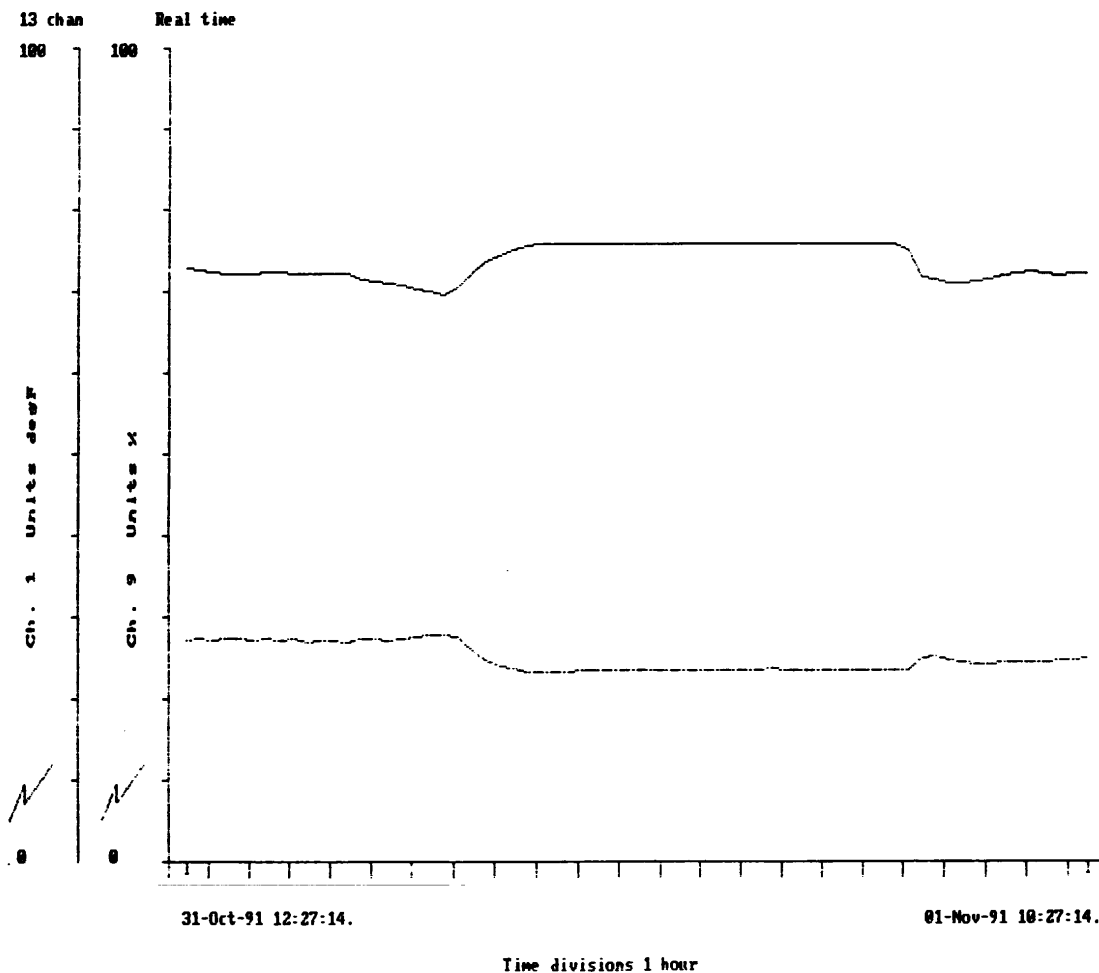
Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 3
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 31-Oct-91 12:27:14.
Finish : 01-Nov-91 10:34:19.
Readings per channel: 67



Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 3
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 31-Oct-91 12:27:14.
Finish : 01-Nov-91 10:34:19.
Readings per channel: 67

Channel 1 Statistics

Sample Period
Start 31-Oct-91 12:27:14. Finish 01-Nov-91 10:27:14.

Range = -57.98degF to 302.04degF
Minimum Value = 69.48degF 31-Oct-91 18:47:14.
Maximum Value = 75.69degF 31-Oct-91 21:27:14.
Mean = 73.43degF
Standard Deviation = 2.07
Variance = 4.288

Channel 9 Statistics

Sample Period
Start 31-Oct-91 12:27:14. Finish 01-Nov-91 10:27:14.

Range = 0.00% to 100.00%
Minimum Value = 23.30% 31-Oct-91 20:47:14.
Maximum Value = 27.80% 31-Oct-91 18:47:14.
Mean = 24.90%
Standard Deviation = 1.64
Variance = 2.701

Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 4
Channels used : 13
Recording Interval : 00:05:00.
Non-averaged time interval readings
Recording period :
Start : 01-Nov-91 10:35:41.
Finish : 01-Nov-91 11:00:21.
Readings per channel: 5

Channel 1 Statistics

Sample Period
Start 01-Nov-91 10:35:41. Finish 01-Nov-91 10:55:41.

Range = -57.96degF to 302.04degF
Minimum Value = 72.18degF 01-Nov-91 10:35:41.
Maximum Value = 76.59degF 01-Nov-91 10:55:41.
Mean = 74.32degF
Standard Deviation = 1.64
Variance = 2.678

Channel 9 Statistics

Sample Period
Start 01-Nov-91 10:35:41. Finish 01-Nov-91 10:55:41.

Range = 0.00% to 100.00%
Minimum Value = 17.20% 01-Nov-91 10:55:41.
Maximum Value = 24.70% 01-Nov-91 10:35:41.
Mean = 20.28%
Standard Deviation = 3.11
Variance = 9.674

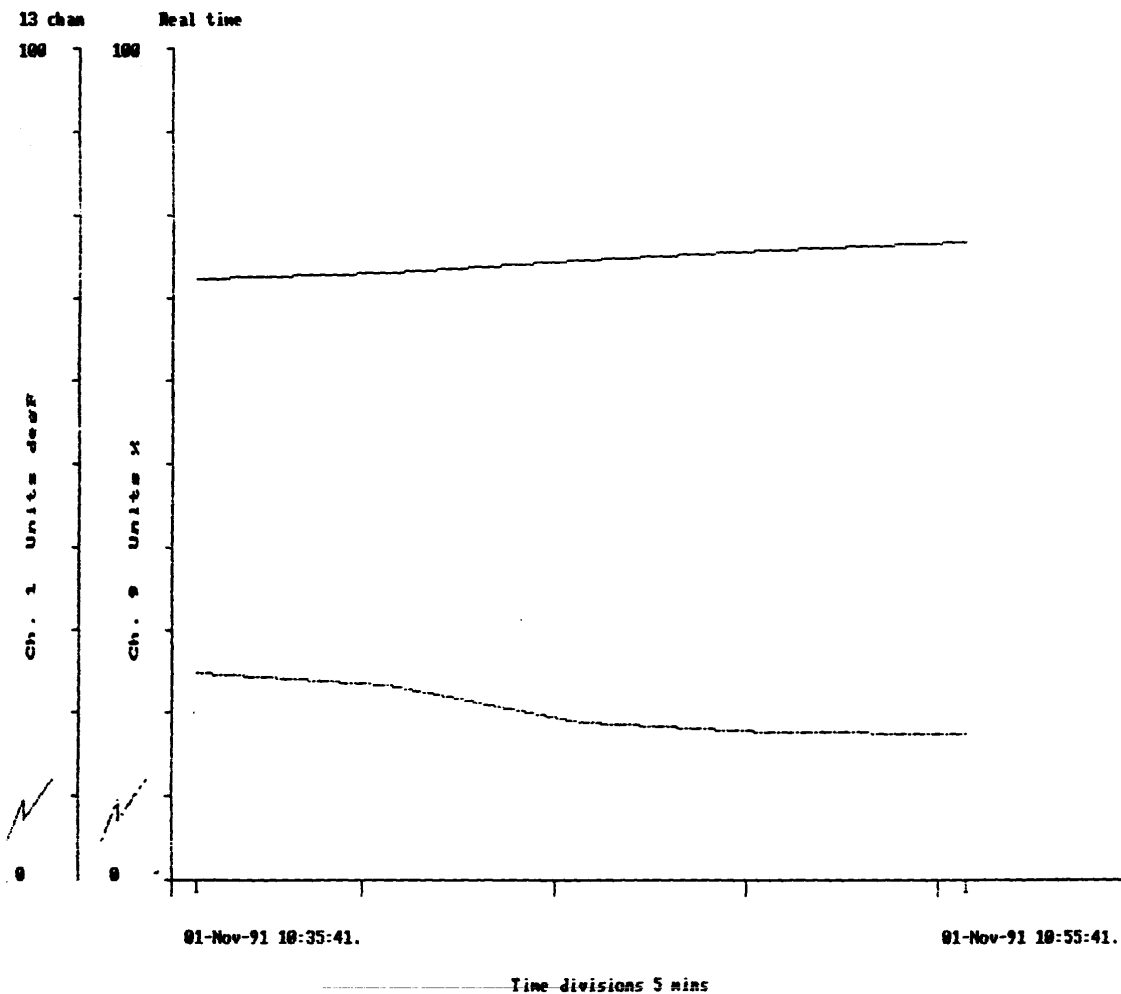
Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 4
Channels used : 13
Recording Interval : 00:05:00.
Non-averaged time interval readings
Recording period :
Start : 01-Nov-91 10:35:41.
Finish : 01-Nov-91 11:00:21.
Readings per channel: 5



Analogous Graph Summary

Run No. 6 -- Storage of Coated Test Specimens in MAE Facility

Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 6
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 01-Nov-91 11:01:06.
Finish : 04-Nov-91 09:08:22.
Readings per channel: 211

Channel 1 Statistics

Sample Period

Start 01-Nov-91 11:01:06. Finish 04-Nov-91 09:01:06.

Range = -57.96degF to 302.04degF

Minimum Value = 68.58degF 03-Nov-91 17:41:06.

Maximum Value = 80.19degF 01-Nov-91 11:21:06.

Mean = 71.57degF

Standard Deviation = 2.63

Variance = 6.924

Channel 9 Statistics

Sample Period

Start 01-Nov-91 11:01:06. Finish 04-Nov-91 09:01:06.

Range = 0.00% to 100.00%

Minimum Value = 10.00% 01-Nov-91 11:21:06.

Maximum Value = 28.40% 01-Nov-91 18:41:06.

Mean = 18.06%

Standard Deviation = 3.87

Variance = 14.978

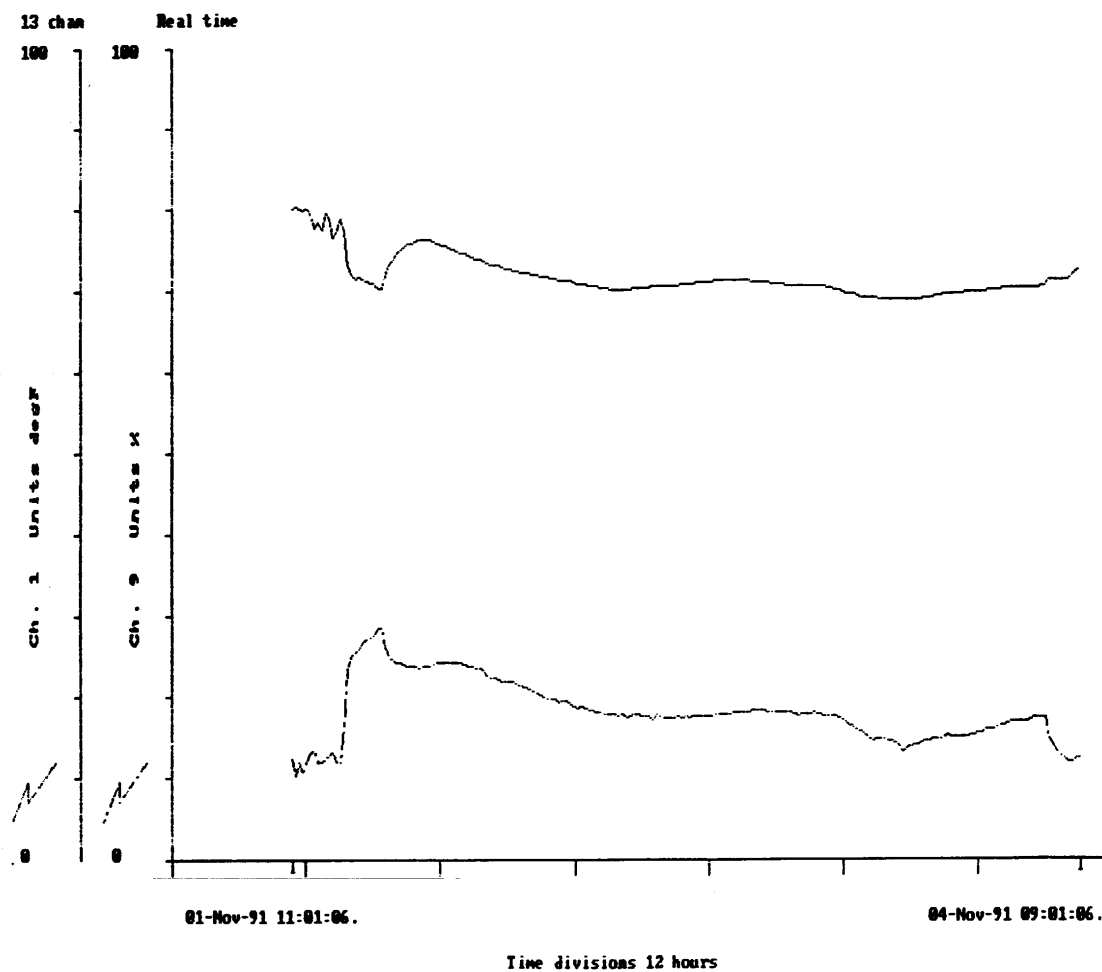
Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 6
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 01-Nov-91 11:01:06.
Finish : 04-Nov-91 09:08:22.
Readings per channel: 211



Run No. 7 -- Transport of Test Specimens to Battelle

Channel Statistics

Data file - NEWARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 7
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
 Start : 04-Nov-91 09:17:11.
 Finish : 04-Nov-91 16:03:46.
Readings per channel: 21

Channel 1 Statistics

Sample Period

Start 04-Nov-91 09:17:11. Finish 04-Nov-91 15:57:11.

Range = -57.96degF to 302.04degF

Minimum Value = 47.61degF 04-Nov-91 09:37:11.

Maximum Value = 72.72degF 04-Nov-91 15:37:11.

Mean = 67.68degF

Standard Deviation = 7.86

Variance = 61.776

Channel 9 Statistics

Sample Period

Start 04-Nov-91 09:17:11. Finish 04-Nov-91 15:57:11.

Range = 0.00% to 100.00%

Minimum Value = 2.10% 04-Nov-91 14:37:11.

Maximum Value = 13.30% 04-Nov-91 09:17:11.

Mean = 5.94%

Standard Deviation = 2.82

Variance = 7.964

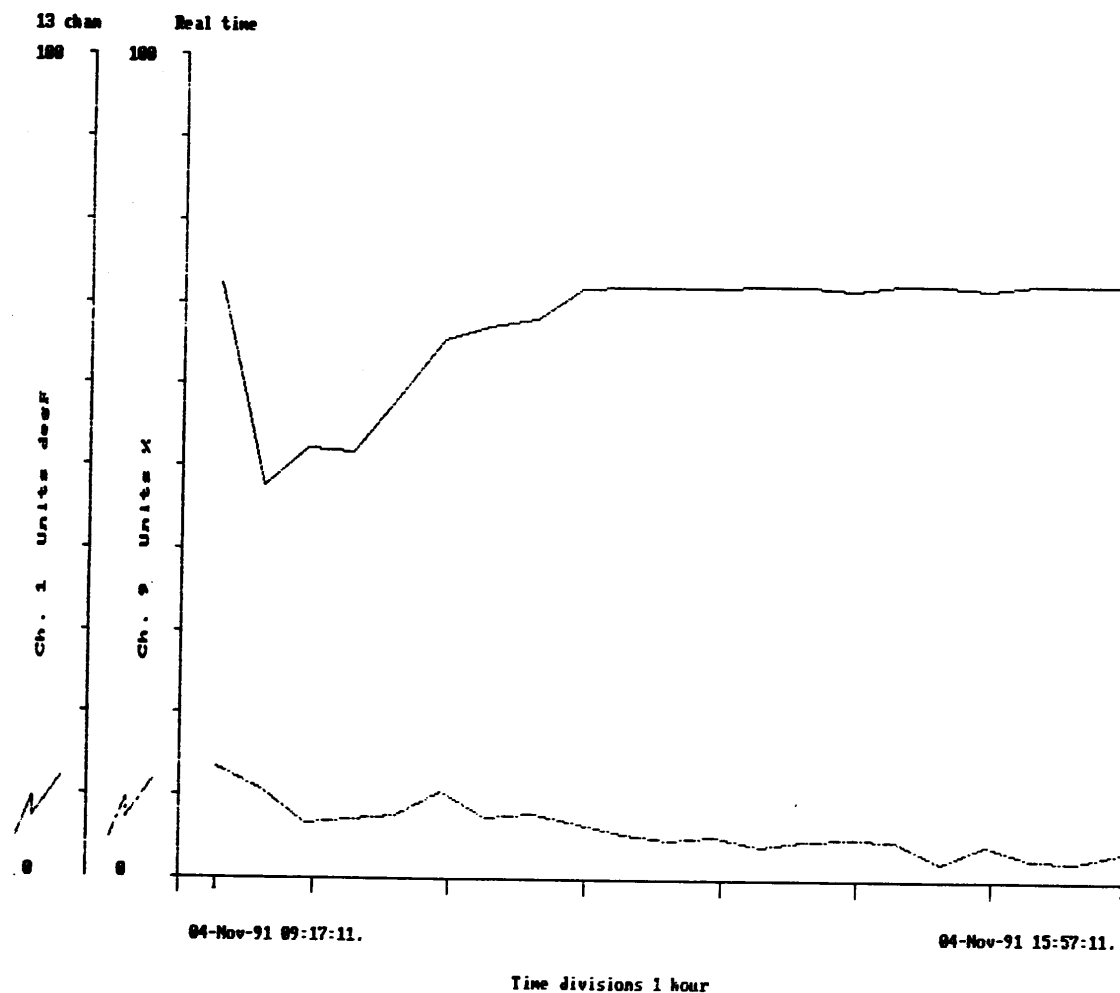
Data file - NEMARK

Recorder details:

Recorder number : 446
Squirrel type : 1201

Run details:

Run number : 7
Channels used : 13
Recording Interval : 00:20:00.
Non-averaged time interval readings
Recording period :
Start : 04-Nov-91 09:17:11.
Finish : 04-Nov-91 16:03:46.
Readings per channel: 21



Analogue Graph Summary

Real time mode

APPENDIX B

Material Safety Data Sheet for MSI-7000 Cleaner

MATERIAL SAFETY DATA SHEET

MSI-7000

Page 1

MAGNASONIC SYSTEMS INC.
788 INDUSTRIAL BLVD.
XENIA, OHIO 45385
(513)372-4811

HEALTH: 1
REACTIVITY: 0
4 = SEVERE 3 = SERIOUS 2 = MODERATE
1 = SLIGHT 0 = MINIMAL

FLAMMABILITY: 0
PERSONAL PROTECTION: 8

EMERGENCY PHONE NUMBER: (513)372-4811

24-HOUR CHEMICAL CONSULTANT: (800)424-9300 SPILLS AND FIRST AID

SECTION I IDENTITY

TRADE NAME: MSI-7000 SYNONYM: AQUEOUS WIPE SOLVENT PRODUCT TYPE: AQUEOUS

SECTION II HAZARDOUS COMPONENTS

HAZARDOUS COMPONENTS	CAS NO.	%	PEL	TLV	MFG.	RECOMMENDATION
CYCLOHEXANOL	108-93-0	5-10	NONE	50 ppm	NONE	RECOMMENDED
2-BUTOXYETHANOL	111-76-2	5-9	50 ppm skin	25 ppm skin	50 ppm skin	

No other hazardous ingredients as listed in 29 CFR 1910.1000 to 1910.1200.
The consultant will advise on clean-up of spills or personnel emergency.

SECTION III PHYSICAL AND CHEMICAL CHARACTERISTICS (FIRE AND EXPLOSION DATA)

BOILING POINT: 212°F SPECIFIC GRAVITY: 1.03
VAPOR PRESSURE: NOT ESTABLISHED VAPOR DENSITY: NOT ESTABLISHED
EVAPORATION RATE: LIKE WATER PERCENT VOLATILE: 40-45
SOLUBILITY IN WATER: COMPLETE REACTIVITY IN WATER: NONE
MELTING POINT: NONE pH IN CONCENTRATE: 11.5
pH 1% IN WATER: 10.0 APPEARANCE: CLEAR LIGHT TO STRAW LIQUID
FLASH POINT: NONE METHOD USED - TAG CLOSED CUP (TCC) ASTM D56
AUTO IGNITION TEMPERATURE: NOT APPLICABLE - AQUEOUS SOLUTION
FLAMMABLE LIMITS IN AIR: UPPER: NOT APPLICABLE LOWER: NOT APPLICABLE
EXTINGUISHER METHOD: CO₂, WATER, FOAM. USE APPROPRIATE FOR FIRE SOURCE.
UNUSUAL FIRE AND EXPLOSION: NONE SPECIAL. USE NIOSH APPROVED RESPIRATOR.

SECTION IV PHYSICAL HAZARDS AND REACTIVITY

STABILITY: STABLE INCOMPATIBILITY: OXIDIZER
HAZARDOUS DECOMPOSITION PRODUCTS: UNDER FIRE CONDITIONS, OXIDES OF NITROGEN,
OTHER HYDROCARBONS.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
REACTS VIOLENTLY WITH: OXIDIZERS
OTHER HAZARDOUS: NONE KNOWN

SECTION V HEALTH HAZARD

ACUTE SYMPTOMS OF OVER EXPOSURE: EYES MAY BE IRRITATED BY CONTACT WITH THIS
PRODUCT. SWALLOWING MAY CAUSE ACUTE INTESTINAL PROBLEMS.
CHRONIC SYMPTOMS OF OVER EXPOSURE: REPEATED OVER EXPOSURE MAY CAUSE HEMOLYSIS,
POSSIBLE KIDNEY AND LIVER DAMAGE.
IS CHEMICAL OR CONSTITUENT LISTED AS A CARCINOGEN: NO
NATIONAL TOXICOLOGY PROGRAM: NO I.A.R.C. MONOGRAPHS: NO OSHA: NO
IS CHEMICAL OR CONSTITUENT LISTED AS MUTAGEN: YES TERATOGEN: YES
OTHER HEALTH HAZARD OR QUALIFYING STATEMENTS: UNION CARBIDE'S REPORT OF
FEBRUARY 1, 1987; REPORTS NO MUTAGENICITY OR TERATOGENICITY AS HIGH AS 100
ppm, NO BLOOD HEMOLYSIS IN HUMANS AS HIGH AS 200 ppm.
COMPONENT TOXICITY AND ROUTES OF ENTRY
EYES: NOT TESTED
SKIN: LD50 2-BUTOXYETHANOL RABBIT 0.7 ml/Kg LD50 CYCLOHEXANOL RABBIT 12 mg/Kg
ORAL: LD50 2-BUTOXYETHANOL RAT 2.7 ml/Kg LD50 CYCLOHEXANOL RAT 2060 mg/Kg
INHALATION (GASES): NOT TESTED
INHALATION (DUSTS): NOT TESTED
OSHA TOXICITY: NOT CLASSIFIED

MATERIAL SAFETY DATA SHEET

MSI-7000

Page 2

SECTION VI EMERGENCY AND FIRST AID PROCEDURES

EYES: Flush eyes for at least 15 minutes with water. If irritation persists, get medical attention.

SKIN: Rinse contact area with water for at least 15 minutes.

INHALATION: Not known to be a problem. Remove affected person to fresh air if there is a sensitivity.

INGESTION: DO NOT INDUCE VOMITING. Obtain medical assistance.

NOTES TO PHYSICIAN: None special.

SECTION VII PERSONAL PROTECTION

VENTILATION TYPE AND AMOUNT: NORMAL AIR FLOW

SPECIAL RESPIRATORY PROTECTION: NONE GENERALLY REQUIRED

SKIN PROTECTION: RUBBER GLOVES

EYE PROTECTION: SAFETY GLASSES

OTHER EQUIPMENT: EYEWASH STATION OR EQUIVALENT

SECTION VIII ENVIRONMENTAL PROTECTION

PROCEDURE IN CASE OF SPILL: Absorb with absorbent material and drum for land fill or flush to effluent treatment system.

WASTE DISPOSAL: Product is biodegradable. Always check with local authorities before releasing any substance.

CERCLA REPORTABLE QUANTITY: NONE SARA REPORTABLE QUANTITY: NONE

RCRA WASTE CODE: NONE (IF DISCARDED AS PURCHASED)

SECTION X HANDLING REQUIREMENTS

PRECAUTION LABELS: SEE SECTION V - ACUTE SYMPTOMS

LABEL SIGNAL WORD: CAUTION

DOT SHIPPING LABEL: NONE

HAZARD CLASS: NONE

UN/NA NUMBER: NONE

SUBSIDIARY RISK: NONE

STORAGE REQUIREMENTS: NORMAL STORAGE. STORE AWAY FROM OXIDIZERS.

HANDLING REQUIREMENTS: USE GOOD INDUSTRIAL PRACTICE. WEAR APPROPRIATE GEAR WHEN TRANSFERRING. SEE SECTION VII. MOVE WITH BUNGS IN PLACE.

SECTION XI REFERENCES

REGISTRY OF TOXIC EFFECTS OF CHEMICAL SUBSTANCES

QUARTERLY MICROFICHE JULY 1987

40 CFR 261.22 29 CFR 1910.1000-.1200

THRESHOLD LIMIT VALUES FOR CHEMICAL SUBSTANCES IN THE WORK ENVIRONMENT

ACGIH 1986/1987 "FOURTH REPORT ON CARCINOGENS", NTP 1985

DAINGEROUS PROPERTIES OF INDUSTRIAL MATERIALS, IRVING SAX, 6TH EDITION

OSHA SHEETS FROM RAW MATERIALS SUPPLIERS

MSDS CONTROL NUMBER: MSI-7000 REVISED DATE: 10/1/91 SUPERSEDES: 9/9/89

AUTHOR: M.B. SPRIGGS, VICE PRESIDENT

The responsibility to provide a safe work place remains with the user. The user should consider the health hazard and safety information contained herein as a guide and should take those precautions required in an individual operation to instruct employees and develop work practice procedures for a safe work environment.

The information contained herein is, to the best of our knowledge accurate. However, since the conditions of handling and use are beyond our control, we make no guarantee of results, and assume no liability for damages incurred by use of this material.

It is the responsibility of the user to comply with all applicable Federal, State and local laws and regulations.

